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(71) Applicant: ERICSSON, INC. [US/US]; 7001 Development Drive, Research Triangle Park, NC 27709 (US).

(72) Inventors: SHEN, Qun; 110 Connors Circle, Cary, NC 27511 (US). LENZO, Michael; 314 Widdington Lane, Apex, NC 27502 (US).

(74) Agent: BENSON, Joel, W.; Brinks Hofer Gilson & Lione, P.O. Box 10087, Chicago, IL 60610 (US).



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(54) Title: AN IMPROVED ANTENNA DIVERSITY SWITCHING SYSTEM FOR TDMA-BASED TELEPHONES

(57) Abstract


A system for selecting an antenna from a diversity of antennas in a DECT, PWT, or TDMA–based antenna selection and switching system is disclosed. When signals are received from a plurality of antennas, the wireless antenna selection and switching system automatically selects either a real–time or a time–delayed signal authentification process. The selected process then selects the antenna that will provide the clearest signal quality.

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# AN IMPROVED ANTENNA DIVERSITY SWITCHING SYSTEM FOR TDMA-BASED TELEPHONES

## BACKGROUND OF THE INVENTION

The present invention relates to a process for selecting an antenna in a wireless communication system having at least two antennas. In particular, the present invention is designed to select the best antenna based on real and time delayed quality indicators.

In wireless communication systems, incoming signals often experience time dispersion and fading which is referred to as multipath effect. Multipath effect occurs when a signal and its replica arrive at a receiver out of phase to any extent. Generally, multipath effect occurs because artificial and natural obstructions cause transmitted signals to follow several propagation paths from a transmitter to a receiver. In wireless technology, the phase differences of the signals arriving at the receiver produce background noise, and in severe cases, cause the receiver to squelch. Conventional wireless technology utilizes antenna diversity to minimize this problem. A wireless network commonly includes more than one antenna positioned such that the signals received by the antennas are not correlated.

In DECT (Digital Enhanced Cordless Telephony) and PWT (Personal Wireless Telephony) systems, for example, two antennas are available in the base station and/or portable. FIG. 1 and FIG. 2 illustrate a conventional wireless system configuration that includes a base station and a portable having two antennas.

When more than one antenna is used in a wireless system, a protocol is employed to select the best antenna. Normally, antenna selection is based on a singular quality indicator adapted from the field of cryptography. The kinds of quality indicators may be divided into two categories namely: (1) those which are designed to authenticate signal transmissions and select an antenna as the signal is received and (2) those which are designed to

authenticate signal transmissions and select an antenna after the signal is received. Known devices of both types have drawbacks and disadvantages.

In a TDMA-based system, for example, the antenna selection is controlled by software or logic circuitry. In this system, a cyclical redundancy check (CRC) like parameter is generally used to select an antenna after the signal is received. CRC is based on polynomial division in which each bit of a packet of data represents one coefficient of a polynomial. The polynomial is then divided by a pre-programmed polynomial to yield a quotient polynomial and in some cases a remainder polynomial. When the division yields a remainder polynomial, the system assumes that a transmission error occurred and selects another antenna. If, however, the division does not yield a remainder polynomial, the system assumes no transmission errors occurred and therefore does not select another antenna.

The antenna selection process is illustrated in FIG. 3. A CRC error rate that produces good speech quality is used as a threshold for selecting an appropriate antenna. If the present antenna provides a CRC error that is below the threshold value, no switching occurs. However, when the CRC error rate rises above the threshold value, another antenna is selected.

While CRC provides antenna selection by authenticating transmitted data, it has disadvantages. Its primary shortcoming is that antenna selections are not made in real time. The present antenna selected is based on a previous CRC comparison which does not change until the antenna receives a poor quality signal. The time delay that exists between receiving an incoming signal and selecting another antenna makes the selection process susceptible to error due to interference. A CRC selection may be accurate if a transmitter or receiver is stationary or moves at a slow rate of speed, because the communication environment is subject only to slight variations in time. However, when a transmitter or receiver moves at a high rate of speed, this time delayed process may be ineffective because it may not react to a changing environment and thus, it may be susceptible to interference.

Another technique for antenna diversity switching authenticates signal transmissions and selects an antenna as the signals are received. Preamble diversity switching is an example of a system that provides real-time measurements and real-time antenna selection. Preamble diversity switching sequentially measures the receive signal strength of a diversity of antennas at the beginning of each extended preamble. The receive signal levels of each antenna, which are the Receive Signal Strength Indicators (RSSI), are stored and compared. The antenna with the higher RSSI value is selected. When the RSSI value associated with another antenna is higher, that antenna is then selected. An example of a preamble diversity switching process is shown in FIG. 4.

The preamble diversity switching process provides the benefit of selecting an antenna as signals are received. The system is less affected by rapid environmental change. However, problems arise when differences between RSSI values are insignificant. When insignificant differences exist, the system may experience some uncertainty when selecting an antenna. This is simply because minor differences in RSSI values indicate that the signal qualities received by the antennas are similar and therefore, an antenna selection will not necessarily improve receiving quality. Therefore, a preamble diversity switching process alone may not be the best parameter for selecting an antenna. An additional indicator may be desirable to select an optimal antenna.

It is therefore an object of the invention to provide an improved antenna selection process for a TDMA-based telephone communication system. In this disclosure, a TDMA / PWT based system is illustrated. –

Another object of the invention is to implement an appropriate decision strategy that considers the limitations of the signal authenticating processes and the error rates of signal transmissions.

Still another object of the invention is to provide an improved antenna selection process for TDMA-based systems that may employ more than two antennas.

## SUMMARY OF THE INVENTION

Pursuant to the invention, a wireless antenna selection and switching system is provided which is capable of selecting an antenna from a diversity of antennas. The antenna diversity switching system is capable of measuring signal quality. When signals are received from a piurality of antennas, the wireless antenna selection and switching system automatically selects a real-time or a time-delayed signal authentication process. The chosen process then selects the antenna that will provide the clearest signal quality.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a conventional wireless base station having a diversity of antennas.

FIG. 2 is a block diagram of a conventional wireless portable station having a diversity of antennas.

FIG. 3 is a block diagram of a Cyclical Redundancy Check antenna switching process used in the prior-art stations of FIG. 1 and FIG. 2.

FIG. 4 is a block diagram of a Preamble Diversity Switching Process also used in the prior-art stations of FIG. 1 and FIG. 2.

FIG. 5 is a flow chart of a first embodiment of the antenna switching process.

FIG. 6 is a flow chart of an alternative embodiment of the antenna switching process.

FIG. 7 is a schematic diagram of the of the antenna switching system used in the antenna switching process of FIG. 5.

FIG. 8 is a schematic diagram of the antenna switching system used in the antenna switching process of FIG. 6.

## DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS

In accordance with a first embodiment, an antenna selection system is illustrated in FIGS. 5 and 7. Here, a preamble diversity switching (PDS) process, a primary means, and a cyclical redundancy check (CRC), a secondary means, are used to select an antenna in systems having a plurality of antennas.

According to the first embodiment, radio frequency broadcasts are sequentially processed into receive signal strength indicators $RSSI_0$ and $RSSI_1$ and are stored, where $RSSI_0$ is measured from a first antenna ($Antenna_0$) and $RSSI_1$ is measured from a second antenna ($Antenna_1$) as illustrated in FIG. 5 (steps 502 and 504). $RSSI_0$ and $RSSI_1$ are then compared to generate a RSSI difference signal ($\Delta$RSSI). (step 506) When $\Delta$RSSI is greater than or equal to a first predetermined quality threshold value $T_1$, the antenna having the highest RSSI value is selected and an N-bit counter is reset. (steps 508 and 512) However, when $\Delta$RSSI is less than $T_1$, the N-bit counter is incremented and then compared to a predetermined slot count $N_1$. (steps 508 and 510) If the value of the N-bit counter is less than $N_1$, protocol requires that the preamble diversity switching process begin a new cycle. (step 510) If, however, the value of the N-bit counter is equal to or greater than $N_1$, protocol initiates CRC control. (step 510)

As previously described, the CRC like parameter authenticates data after the data is received as in a batch mode. In this process, the transmitted signal is encoded with a circular redundant code derived from the signal's content. The signal is received and decoded into a CRC error rate. (step 514) The CRC error rate is then compared to a second predetermined quality threshold value, $T_2$. (step 516) When the CRC error rate exceeds $T_2$, another antenna is selected and control is returned to the preamble switching process. (steps 516 and 518) When the CRC error rate is equal to or is less than $T_2$, no switching occurs and again control is returned to the preamble switching process. (step 516) In this embodiment a predetermined CRC error rate is used as the threshold $T_2$ to ensure high quality data and audio communications. A CRC error rate of 1%, for example, may be used as the

threshold $T_2$ for audio communications, because a CRC error rate below 1% generally produces good voice quality.

The hardware implementation of the first embodiment will now be described. As depicted in FIG. 7, when the broadcast signals are received the signals are processed using a PDS circuit 702. The PDS circuit 702 produces the ΔRSSI signal which is fed to a comparator circuit 704 by a first output. When the ΔRSSI is greater than or equal to the first predetermined quality threshold value $T_1$, the comparator 704 resets an N-bit counter circuit 706 and enables a latch circuit 708. The latch circuit 708 latches a second output from the PDS circuit 702 to a multiplexer circuit 710 enabled by the N-bit counter circuit 706 to make the antenna selection. Once the ΔRSSI falls below $T_1$, the counter circuit 706 is incremented in response to a third output from the PDS control circuit 702. In this embodiment, after more than $N_1$ consecutive low ΔRSSI cycles, control of the antenna selection is transferred to a CRC circuit 712 by the N-bit counter circuit's 706 control of the multiplexer circuit 710. The CRC circuit 712 then controls antenna selection until the ΔRSSI equals or exceeds $T_1$. When ΔRSSI equals or exceeds $T_1$, the PDS circuit 702 resumes control of the selection process and the comparator circuit 704 resets the counter circuit 710.

According to a second embodiment, the real-time signal authentication process or real mode controls the selection of the antenna even when ΔRSSI is less than $T_1$. Referring now to FIG. 6, the process is identical to FIG. 5 with one exception. (step 610) When the difference signal, ΔRSSI, is less than the threshold $T_1$ a new cycle is not initiated. (step 610) When the N-bit counter is less than $N_1$, the antenna having the highest RSSI value is selected. (steps 610 and 612)

The hardware implementation of the second embodiment is similar to the first embodiment and therefore, identical circuits are labeled with the same reference numbers. As can be readily observed from FIGS. 7 and 8, the absence of the latch circuit 708 enables the selection of the antenna having the highest RSSI value even when ΔRSSI, is less than $T_1$. The N-bit

counter circuit 706 does not enable the multiplexer circuit 710 to select CRC circuit 712 control until the N-bit counter 706 exceeds $N_1$.

According to a third embodiment, memory is added to the N-bit counter circuit 706. Memory facilitates base station applications by allowing this embodiment to track the location of multiple portables and identify the combination of authentication processes most frequently utilized.

The embodiments previously described use counters, threshold comparators, digital multiplexers, PDS and CRC circuits. The various parameters including $T_1$, $T_2$, and $N_1$ vary according to the environment of the embodiment's use as rural and urban areas have different receiving characteristics. It should also be noted that other real-time and time delayed or batch time authentication selection processes may be employed.

Many changes and modifications can be made to the form of the invention without departing from its spirit. The foregoing detailed description is intended to be illustrative rather than limiting and it is understood that the following claims are intended to define the scope of the invention.

WE CLAIM:

1. An antenna selection and switching system which is capable of selecting an antenna from a diversity of antennas by verifying the integrity of electronic signals received from said diversity of antennas in a wireless-type communication system, wherein the system comprises:

a preamble diversity switching process linked to said diversity of antennas for automatically differentiating signal quality as the signals are received;

a cyclical redundancy code process linked to said diversity of antennas for automatically differentiating signal quality after the signals are received; and

determination means coupled to said preamble diversity switching process and said cyclical redundancy code process, wherein said determination means alternatively employs said preamble diversity switching process and said cyclical redundancy code process for providing said antenna selection.

2. An antenna selection and switching system as defined in claim 1, wherein said determination means is responsive first to the operability of said preamble diversity switching process and second to the operability of said cyclical redundancy code process.

3. An antenna selection and switching system as defined in claim 1, wherein said determination means for selecting said antenna further comprises an N-bit counter for selectively delaying said antenna selection.

4. An antenna selection and switching system as defined in claim 1, wherein said wireless-type communication system is a TDMA-based telephone system.

5. An antenna selection and switching system as defined in claim 3, wherein said N-bit counter is programmable and has a memory array for storing information corresponding to the location of a plurality of portables.

6. An improved system for selecting a single antenna in a wireless-type telephone communication system which is capable of authenticating transmitted signals, comprising:

a diversity of antennas;

primary means switchably coupled to said diversity of antennas for authenticating said signals and selecting said single antenna in real time;

secondary means switchably coupled to said diversity of antennas for authenticating said signals and selecting said single antenna after said signals are received; and

protocol means controllably coupled to said primary means and said secondary means for transferring said antenna selection between said primary means and said secondary means.

7. The system as defined in claim 6, wherein said signals are digitally transmitted data.

8. The system as defined in claim 6, wherein said protocol means for transferring said antenna selection is responsive to the operability of said primary means.

9. The system as defined in claim 6, wherein said primary means and said secondary means verifies the integrity of digital and analog signals.

10. The system as defined in claim 6, wherein said diversity of antennas transmit and receive data.

11. An antenna diversity switching device used in a TDMA based communication system which is capable of selecting a single antenna from a plurality of antennas in response to the quality of signals received from said plurality antennas, wherein the system comprises:

means for detecting said signal quality in both

a real mode responsive to said signal quality measured as said signals are received; and

a batch mode responsive to said signal quality measured after said signals are received; and

a controller operatively linked to said detection means for selecting said single antenna in response to one of said detection means.

12. The antenna diversity switching device as defined in claim 11, wherein said controller is interfaced to a counter having advancing means for delaying said selection of said antenna until the value of said counter equals the value of a predetermined number.

13. The antenna diversity switching device as defined in claim 11, wherein said controller is interfaced to a programmable numerical counter having advancing means for delaying said controllers selection of said antenna in said batch mode until the value of said counter equals the value of a predetermined number.

14. The antenna diversity switching device as defined in claim 11, wherein said controller's selection of said antenna in response to said real mode detection means is delayed until said received signal quality at least equals a first predetermined quality threshold.

15. The antenna diversity switching device as defined in claim 11, wherein said controller's selection of said antenna in response to said batch

mode detection means is delayed until said received signal quality exceeds a second predetermined quality threshold.

16. The antenna diversity switching device as defined in claim 12, wherein said controller resets said counter to a pre-set value on selection of said single antenna in response to said real mode detection means.

17. A TDMA-based diversity antenna switching system for selecting a single antenna comprising:

a plurality of antennas for receiving signals;

a first controller switchably linked to said plurality of antennas for authenticity said received signals and selecting said single antenna as a signal is received;

a second controller switchably linked to said plurality of antennas for authenticity said received signals and selecting said single antenna after a signal is received; and

a switching device controllably linked to said first and second controllers for selecting one of said first and second controllers.

18. The TDMA-based diversity antenna switching system as defined in claim 17, wherein said switching device is responsive to said first controller.

19. The TDMA-based diversity antenna switching system as defined in claim 17, wherein said switching device includes means for delaying said antenna selection.

20. An improved wireless diversity antenna switching system capable of verifying the quality of a spectrum of TDMA-based signals, comprising:

a plurality of antennas for receiving signals;

a switching device switchably connected to said plurality of antennas, said switching device responsive to said signal quality for selecting a single antenna;

a first controller communicating with said switching device and operative when said switching device selects said antenna using a preamble diversity switching process; and

a second controller cooperating with said first controller and operative when said switching device selects said antenna using a cyclical redundancy code process.

21. A method of selecting a TDMA-based telephone communication antenna for receiving signals, said method comprising:

receiving said signals from a plurality of antennas;

processing said signals alternatively in a real time mode and in a batch time mode; and then

selecting said antenna from said plurality of antennas by verifying the authenticity of said received signals in response to one of said processing modes.

22. A method of selecting a TDMA-based telephone communication antenna, comprising:

selecting a TDMA-based telephone antenna from a first process in which said antenna is selected by a preamble diversity switching process in real time to a second process in which said antenna is selected by a cyclical redundancy code process in batch time.

23. An improved system for selecting a single antenna in a DECT/PWT-based telephone communication system which is capable of selecting a single antenna from a plurality of antennas in response to the quality of signals received from said plurality antennas, wherein the system comprises:

a preamble diversity switching process switchably coupled to said diversity of antennas for authenticating said signals and selecting said single antenna based on a received signal preamble integrity;

a cyclical redundancy code process switchably coupled to said diversity of antennas for authenticating said signals and selecting said single antenna based on a received cyclical redundancy code integrity; and

protocol means controllably coupled to said preamble diversity switching process and said cyclical redundancy code process for transferring said antenna selection to one of said processes.

24. The antenna selection system as defined in claim 23, wherein said protocol means for selecting said antenna further comprises an N-bit counter for selectively delaying said antenna selection.

25. The antenna selection system as defined in claim 23, wherein said controller's selection of said antenna in response to said preamble diversity switching process is delayed until said received signal quality at least equals a first predetermined quality threshold.

26. The antenna selection system as defined in claim 23, wherein said controller's selection of said antenna in response to said cyclical redundancy code process is delayed until said received signal quality exceeds a second predetermined quality threshold.

27. The antenna selection system as defined in claim 24, wherein said N-bit counter is programmable and has a memory array for storing information corresponding to the location of a plurality of portables.

FIG. 1

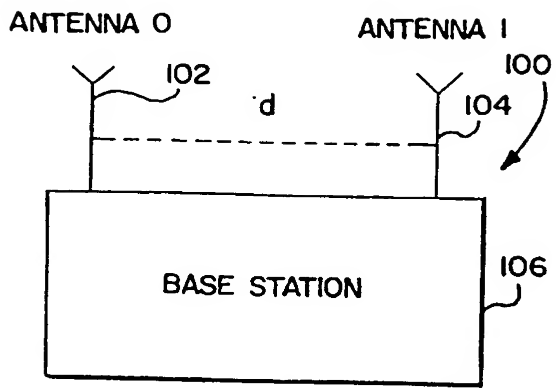



FIG. 2

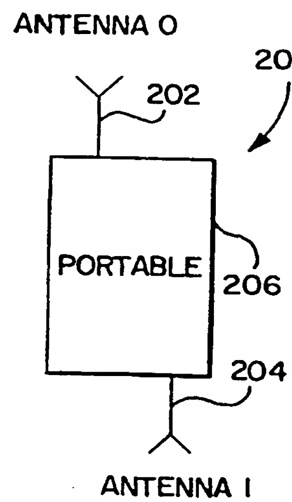



FIG. 3

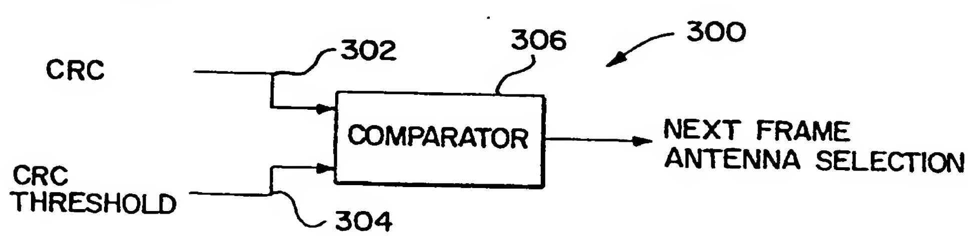



FIG. 4

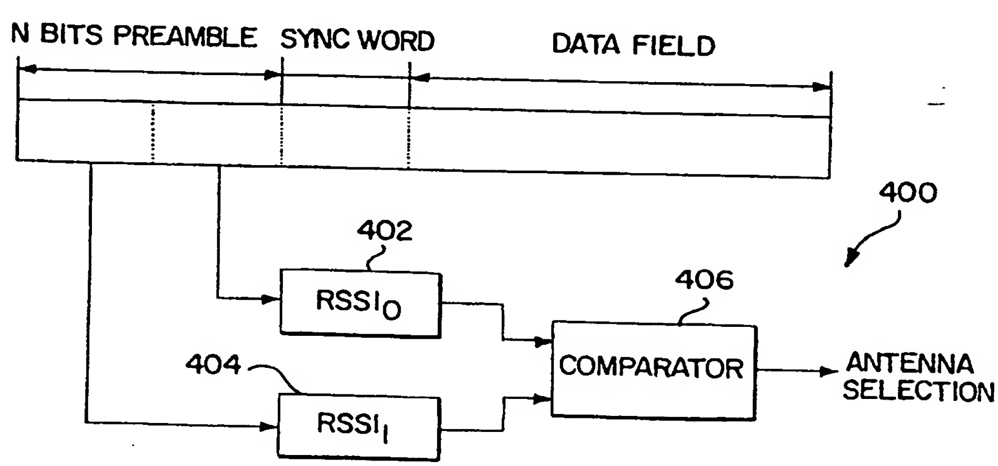
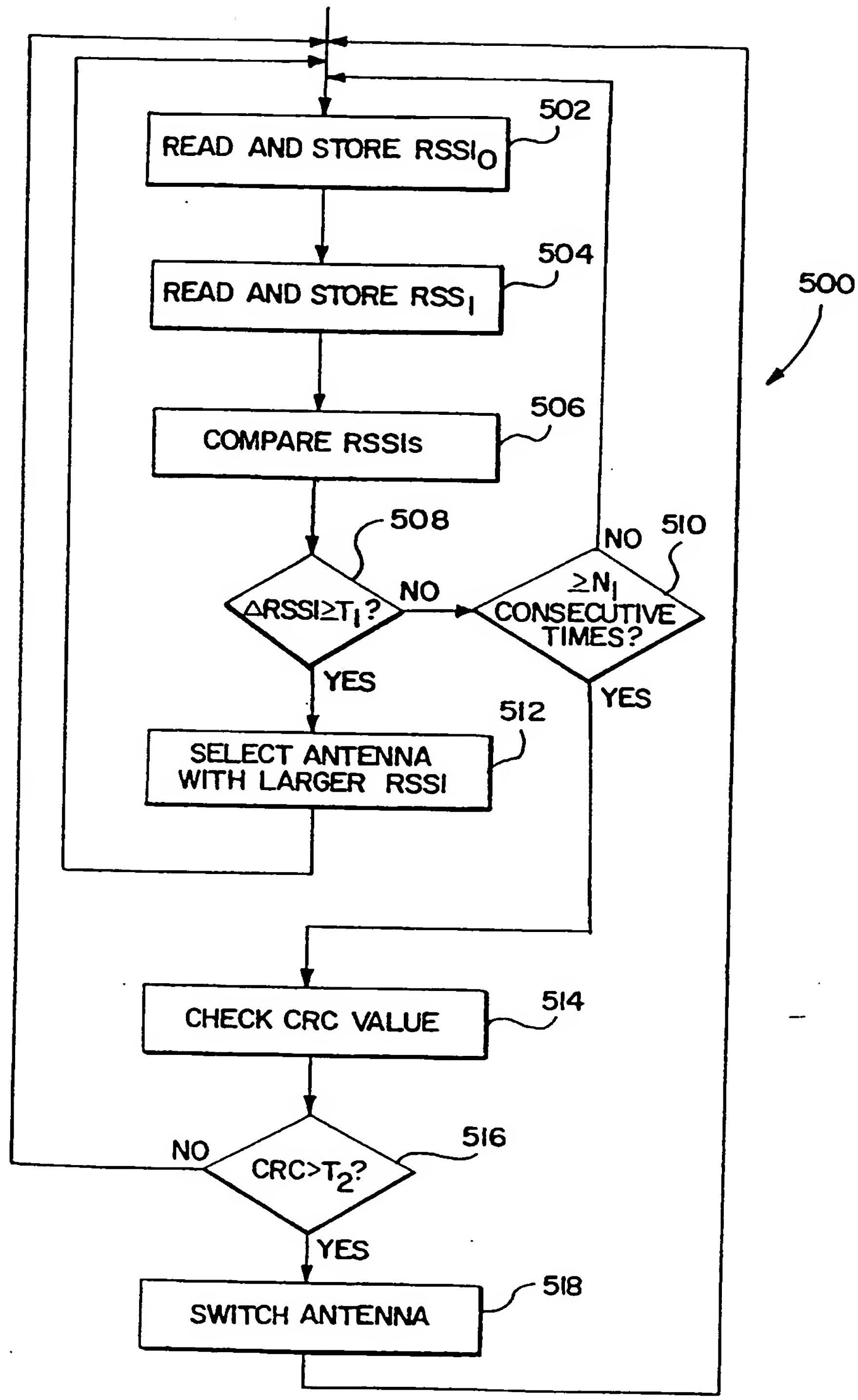


FIG. 5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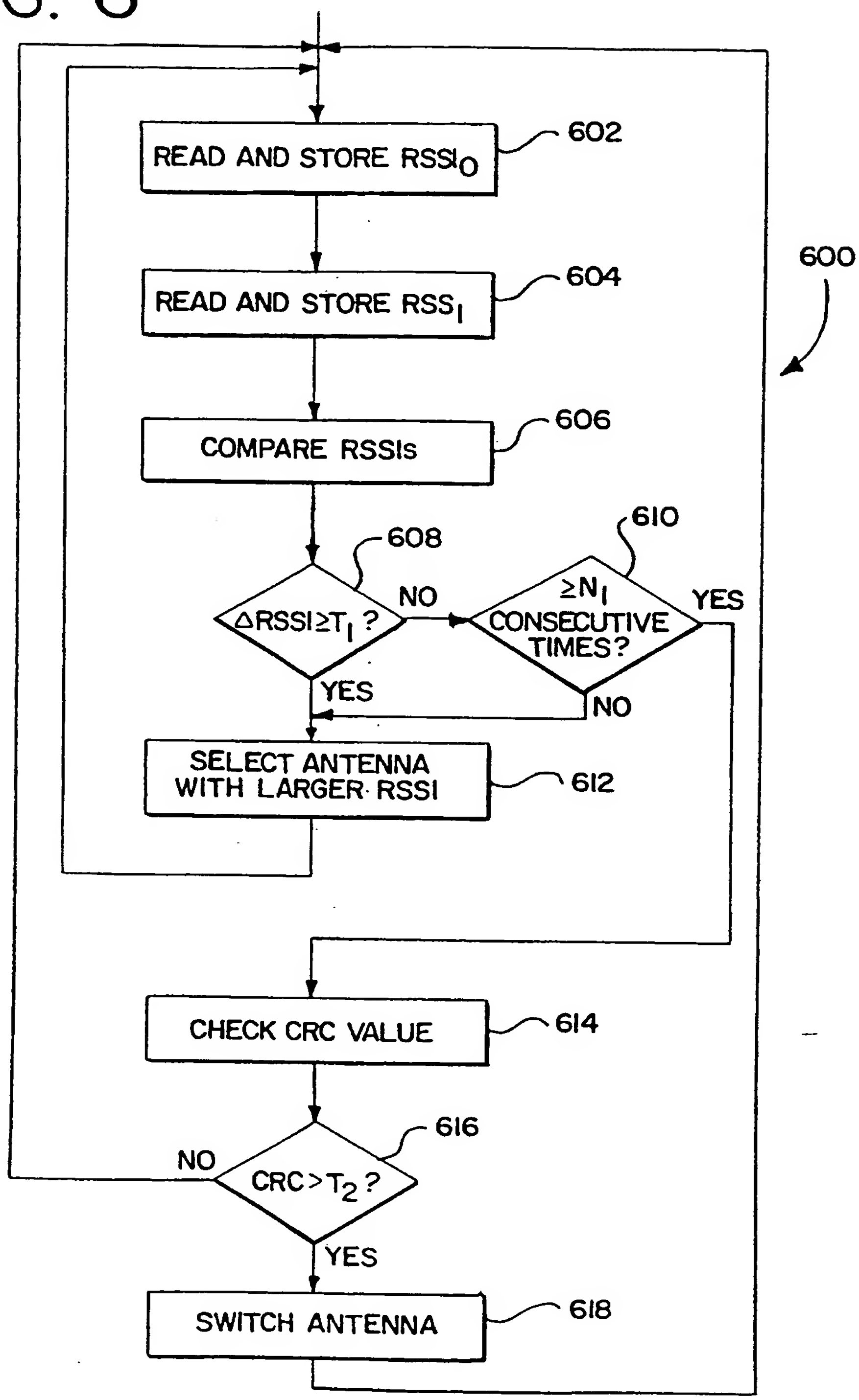
READ AND STORE RSSI0
502
READ AND STORE RSS1
504
COMPARE RSSIs
506
508
ΔRSSI≥T1?
NO
YES
≥N1 CONSECUTIVE TIMES?
510
NO
YES
SELECT ANTENNA WITH LARGER RSSI
512
CHECK CRC VALUE
514
CRC>T2?
516
NO
YES
SWITCH ANTENNA
518

FIG. 6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READ AND STORE $RSS_I$
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600
COMPARE RSSIs
606
608
610
$\Delta RSSI \geq T_I$ ?
NO
$\geq N_I$ CONSECUTIVE TIMES?
YES
YES
NO
SELECT ANTENNA WITH LARGER RSSI
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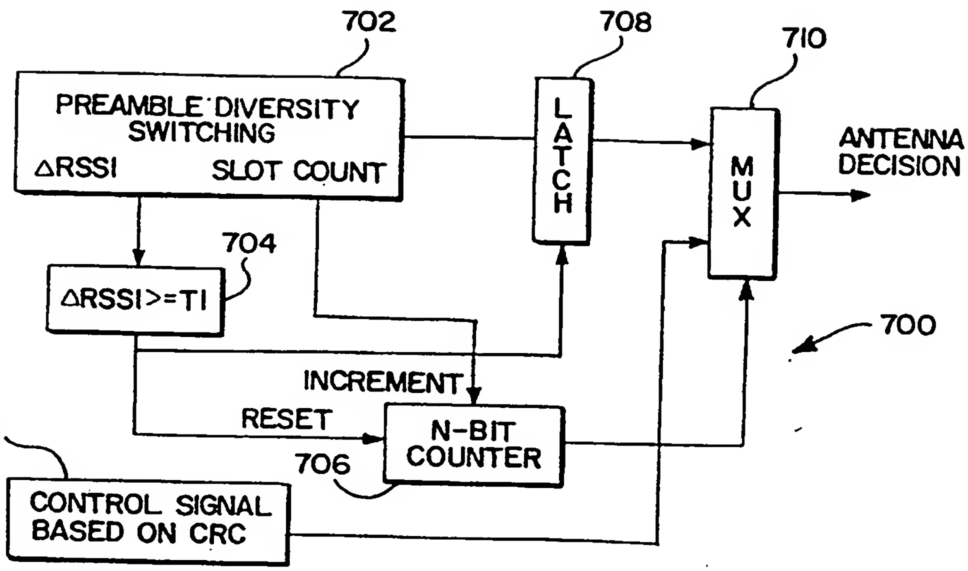
CHECK CRC VALUE
614
616
NO
$CRC > T_2$ ?
YES
SWITCH ANTENNA
618

FIG. 7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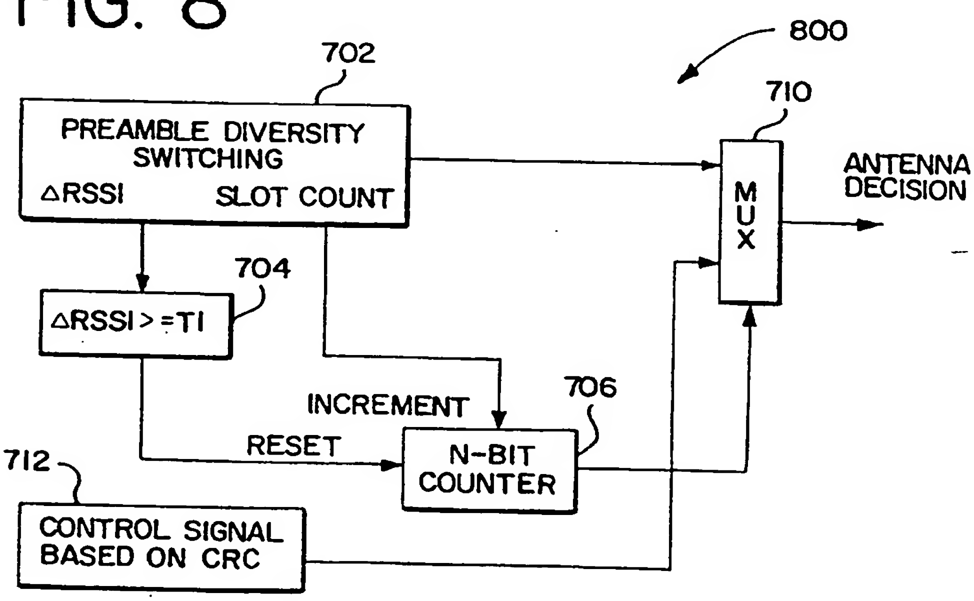
PREAMBLE DIVERSITY SWITCHING
ΔRSSI
SLOT COUNT
LATCH
MUX
ANTENNA DECISION
704
ΔRSSI>=TI
700
INCREMENT
RESET
N-BIT COUNTER
712
706
CONTROL SIGNAL BASED ON CRC

FIG. 8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ΔRSSI>=TI
INCREMENT
706
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N-BIT COUNTER
712
CONTROL SIGNAL BASED ON CRC

# INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 98/27617

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 6 H04B7/08

According to International Patent Classification (IPC) or to both national classification and IPC

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y | SAFAVI S ET AL: "NOVEL TECHNIQUES FOR PERFORMANCE OPTIMISATION OF DECT RECEIVERS WITH NON-LINEAR FRONT-END" 1996 IEEE 46TH. VEHICULAR TECHNOLOGY CONFERENCE, MOBILE TECHNOLOGY FOR THE HUMAN RACE ATLANTA, APR. 28 - MAY 1, 1996, vol. 2, no. CONF. 46, 28 April 1996, pages 824-828, XP000593099 INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS see page 826, right-hand column, line 15 - page 827, left-hand column, line 32 --- | 1-4,6-26 |
| Y | EP 0 755 131 A (HAGENUK TELECOM GMBH) 22 January 1997 see page 4, column 5, line 27 - page 5, column 7, line 24; figure 1 --- | 1-4,6-26 |
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PCT/US 98/27617

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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|---|---|---|
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